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(54) **TCF MUTANT**

(57) The present invention relates to TCF mutant having a novel amino acid sequence which is obtained by mutagenesis of one or more amino acid between N-terminus and the first kringle of the amino acid sequence of native TCF and has lowered affinity to heparin and/or elevated biological activity. The present TCF mutant is prepared by gene manipulation of TCF. The TCF mutants of the present invention have proliferative activity and/or growth stimulative activity in hepatocyte and beneficial as a therapeutic agent for various hepatic diseases and an antitumor agent.

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Description

Field of the Invention

The present invention relates to TCF mutants comprising a novel amino acid sequence, more specifically, TCF mutants which are obtained by mutagenesis of one or more amino acid in the sequence from N-terminus to the first kringle of native TCF and show lowered affinity to heparin and/or elevated biological activity. The TCF mutants of the present invention which show proliferative activity and growth stimulative activity in hepatocyte are beneficial for treatment of various hepatic diseases and as an antitumor agent.

Background of the Invention

Tumor cytotoxic factor (TCF-II) produced in human fibroblast cells is a novel antitumor substance different from any antitumor proteins so far reported. The present inventors have succeeded in cloning of cDNA coding for the protein of the present invention, determined the total amino acid sequence thereof and confirmed usefulness thereof (WO90/10651). The molecular weight of TCF was $78,000 \pm 2,000$, or $74,000 \pm 2,000$ according to the results of SDS electrophoresis under non-reducing conditions, while the results under reducing conditions indicated A-chain of $52,000 \pm 2,000$, common band, B-chain of $30,000 \pm 2,000$ and/or C-chain of $26,000 \pm 2,000$. TCF is a protein which has a high affinity to heparin or heparin-like substance and shows high antitumor activity against tumor cells and proliferative activity to normal cells. Further, it was confirmed that it belongs to a wide variety of family of HGF, a growth factor for hepatocyte. Therefore, since TCF is not only an antitumor factor, but also a growth factor for hepatocytes, it is known that it is beneficial for liver regeneration after hepatectomy.

Many researches have been carried out from the aspects of structure-function relationship of hepatocyte growth factor (HGF) so far. About 20 species of deletion mutants and about 50 species of point mutants have been reported so far (K. Matsumoto, et. al., Biochem. Biophys. Res. Comm., vol. 181, pp691-699 (1991); G. Hartmann, et. al. Proc. Natl. Acad. Sci. USA, vol. 89, pp11574-11587 (1992); N. A. Lokker, et. al., EMBO J. vol. 11, pp 2503-2510 (1992); M. Okigaki et. al., Biochemistry, vol. 31, pp 9555-9561 (1992); N. A. Lokker, et. al. Protein Engineering, vol. 7, pp895-903 (1994)), however, any mutant which clearly shows an elevated biological activity is not obtained at present.

Half-life of TCF in vivo is known to be extremely short, about 2 minutes. Therefore, it is anticipated that a comparatively large amount of the protein should be administered for treatment of various diseases. It is conceivable that the dosage level of TCF administered will be reduced by elevation of biological activity thereof or by prolongation of the half-life thereof in vivo. Though it was described on TCF mutants with prolonged half-life in patent publication WO94/14845, any TCF mutant with elevated biological activity is not obtained at present, like HGF described above.

Therefore, the present inventors have investigated to obtain a TCF mutant which shows elevated biological activity or prolongation of half-life in vivo. More specifically, the present inventors have carried out research to obtain the above-mentioned mutant with elevated biological activity or with prolonged half-life in vivo which is different from native TCF with respect to amino acid sequence by altering the DNA sequence coding for the amino acid sequence of native TCF and expressing DNA thereof. Accordingly, an object of the present invention is to provide a TCF mutant with elevated biological activity or with prolonged half-life in vivo due to lowered affinity to heparin.

The present inventors have eagerly investigated on the above object and obtained novel TCF mutants which have amino acid sequences different from that of TCF mutant found prior to the present invention and show elevated biological activity and/or lowered affinity to heparin. The present invention provides TCF mutants which show more than 10 folds of specific activity (biological activity per unit amount of protein) and/or lowered affinity to heparin.

These are the first mutants with extremely elevated biological activity by mutagenizing the amino acid sequence of native TCF.

Summary of the Invention

An object of the present invention is to provide a TCF mutant with lowered affinity to heparin and/or with elevated biological activity which is obtained by mutagenesis of one or more amino acid residue(s) in the amino acid sequence from N-terminus to the first kringle of native TCF.

Brief Description of Drawings

Figure 1 shows SDS electrophoresis profiles of purified TCF and TCF mutants of the present invention

Figure 2 shows proliferative action of purified TCF and TCF mutants of the present invention in hepatocyte. The relative activity (%) of vertical axis is represented as the ratio of proliferative activity of each sample based on that of 10 ng/ml TCF as 100%.

Figure 3 shows comparison of proliferative action in hepatocytes between purified mutant RKRR2AAAA and TCF.

Figure 4 shows comparison of proliferative action in hepatocytes between purified mutant KIKTKK27AIATAA and TCF.

Figure 5 shows comparison of proliferative action in kidney epithelial cells among purified mutant RKRR2AAAA, mutant KIKTKK27AIATAA and TCF.

Figure 6 shows comparison of proliferative action in bone marrow cells among purified mutant RKRR2AAAA, mutant KIKTKK27AIATAA and TCF.

Figure 7 shows dose effects of purified TCF, mutant RKRR2AAAA and mutant KIKTKK27AIATAA on the serum level of total protein in rats.

Figure 8 shows dose effects of purified TCF, mutant RKRR2AAAA and mutant KIKTKK27AIATAA on the serum level of HDL-cholesterol in rats.

Detailed description of the Invention and Preferred Embodiments

By comparing properties of native protein and a mutant obtained by mutagenesis at some portion of the amino acid sequence of the protein, function of that portion can be estimated. In the case of a protein whose structure is not clearly known, it is often used to substitute an amino acid, such as Ala, which will not affect the steric structure for a polar amino acid supposed to be on the surface of a protein to prevent a structural change of the protein due to the mutagenesis. To site-specifically change one amino-acid sequence of a protein into another, cDNA with site-specific mutations can be prepared by PCR (polymerase chain reaction) method using cDNA coding for native TCF as template and synthetic oligonucleotides coding for the other amino acids.

cDNA obtained as described above can be inserted into a vector having an appropriate expression promotor (cytomegalovirus (CMV), SR α (Mol. Cell. Biol. vol. 8, No.1, pp466-472 (1988) and Japanese Published Unexamined Patent Application 277489 (1989) and transfected into eukaryotic cells, such as mammalian cells. By culturing these cells, objective TCF mutants can be prepared from the culture broth.

Many TCF mutants can be constructed by introducing mutations at different sites or residues. In the present invention, 6 mutants were prepared. These mutants are specified by enumerating the amino acid sequence before mutagenesis, the number of amino acid at N-terminus of mutagenized portion and changed amino acid sequence after mutagenesis by one letter code of amino acid. For example, if the whole sequence of Arg-Lys-Arg-Arg at the second position from N-terminus is replaced with Ala, the mutant is represented as RKRR2AAAA. For another example, mutant whose original sequence Lys-Ile-Lys-Thr-Lys-Lys at 27th position from N-terminus is replaced with Ala-Ile-Ala-Thr-Ala-Ala is represented as KIKTKK27AIATAA.

The present invention will be explained in detail by describing examples. However, these are only exemplified and the scope of the invention will not be limited by these examples.

[Example 1]

Site-specific mutation was introduced by the method described below using the 6.3kb TCF expression plasmid obtained by the method described in WO92/01053. *E. coli* comprising this plasmid was deposited as FERM BP-3479.

I. Preparation of Template Plasmid pcD TCF001

According to the method below, a mutation was introduced at PstI cleavage site of nucleotide number 34 to change to a nucleotide sequence which could not be cleaved. PCR was carried out using 8 ng of plasmid pUC TCF (plasmid in which SalI/SphI fragment of TCF cDNA was inserted into plasmid pUC18) as a template in the presence of a combination of mutagenized primer Pst01 (Seq.Id.No.1) and a nonmutagenized primer TCF415 R (Seq.Id.No.2), and in the presence of a combination of mutagenized primer P002 (Seq.Id.No.3) and a non-mutagenized primer TCFSal-77 (Seq.Id.No.4).

After the primers were removed from the reaction mixture by molecular sieving with microcon 100 (Amicon), the products were mixed. And the second PCR was carried out using primer TCFSal-77 and TCF415R. The obtained product was digested by restriction enzymes BstPI and PstI. By using a ligation kit (Takara-shuzo), the fragment was ligated with the largest BstPI-PstI fragment of pUC TCF BstPI/PstI prepared beforehand. *E. coli* DH5 α was transformed by using a part of the ligation reaction mixture.

Transformed *E. coli* DH5 α was cultured in L broth containing 50 μ g/ml ampicillin and an objective plasmid was selected

from ampicillin resistant colonies. This plasmid was digested by restriction enzymes Sall and SphI, mixed with new pcDNAI (in which multi-cloning site of pcDNAI was mutagenized and there was a HindIII-Sall-BamHI-SphI-NotI cloning site) Sall/SphI large fragment prepared beforehand and inserted by using a ligation kit. Using the reaction mixture, *E.coli* MC1061/P3 (Invitrogen) was transformed. Transformed *E.coli* MC1061/P3 was cultured in L broth containing 50 µg/ml ampicillin and 7.5 µg/ml tetracyclin.

Plasmid DNAs were prepared from obtained ampicillin-tetracyclin resistant colonies and the nucleotide sequence thereof were determined by a DNA sequencer (Perkin-Elmer). Plasmid pcD TCF001 having an objective structure was obtained and TCF mutants were prepared by using the obtained plasmid.

II. Construction of an Expression Vector for TCF Mutants and Preparation of Transformed *E.coli*.

i. Construction of RKRR2AAAA Expression Vector and Preparation of Transformed *E.coli*.

An expression vector for cDNA coding for RKRR2AAAA was constructed by 2 steps of PCR. In the first step, a combination of mutagenized primer 2RKRRF (Seq.Id.No.5) and non-mutagenized primer TCF977 R (Seq.Id.No.6) and a combination of mutagenized primer 2RKRR R (Seq.Id.No.7) and non-mutagenized primer TCFSal-77 (Seq.Id.No.4) were used.

Four nano grams of pcD TCF001 was used as a template in both reactions. After the reactions, both reaction mixtures were admixed and purified with microcon 100. One twentieth of the mixture was used as template in the second PCR. TCFSal-77 and TCF977 R were used as primers. The reaction mixture was purified with microcon 100 and digested by restriction enzymes BstPI and EcoRV. By using the ligation kit, the fragment was inserted into the large fragment of an SR α -containing TCF expression vector cleaved by BstPI and EcoRV beforehand. *E.coli* DH5 α was transformed with the ligation reaction mixture and an objective clone was obtained from the obtained ampicillin resistant cells by the same method as described before. Plasmid DNA was prepared from the obtained clone and the DNA sequence thereof was determined by the DNA sequencer (Perkin-Elmer). And this plasmid was cleaved by restriction enzymes EcoRV and BstPI and inserted into the fragment of pUC TCF digested by restriction enzymes EcoRV and BstPI beforehand, followed by transformation of *E.coli* DH5 α therewith. *E.coli* comprising this plasmid was deposited as pUC TCF2 at National Institute of Bioscience and Human Technology on November 10, 1994 and has a deposit number FERM P-14624.

ii. Construction of KIKTKK27A1ATAA Expression Vector and Preparation of Transformed *E.coli*.

An expression plasmid for cDNA coding for KIKTKK27A1ATAA mutant was constructed by 2 steps of PCR. In the first PCR, a combination of a mutagenized primer 27KIKTKK F (Seq.Id.No.8) and non-mutagenized primer TCF977 R (Seq.Id.No.6) and a combination of mutagenized primer 27KIKTKK R (Seq.Id.No.9) and non-mutagenized primer TCFSal-77 (Seq.Id.No.4) were used. Four ng of pcD TCF001 was used as a template in both reactions. After the reactions, both reaction mixtures were admixed and purified with microcon 100. One twentieth of the mixture was used as template in the second PCR. TCFSal-77 and TCF977 R were used as primers.

The reaction mixture was purified with microcon 100 and digested by restriction enzymes BstPI and EcoRV. By using a ligation kit, the fragment was inserted into the large fragment of the SR α -containing TCF expression vector cleaved by BstPI and EcoRV beforehand. *E.coli* DH5 α was transformed with the ligation reaction mixture and an objective clone was obtained from the obtained ampicillin resistant cells by the same method as described before. Plasmid DNA was prepared from the obtained clone and the DNA sequence thereof was determined by DNA sequencer. And this plasmid was cleaved by restriction enzymes EcoRV and BstPI and incorporated into a fragment of pUC TCF by digested restriction enzymes EcoRV and BstPI, followed by transformation of *E.coli* DH5 α therewith. *E.coli* comprising this plasmid was deposited at National Institute of Bioscience and Human-Technology November 10, 1994 and has the deposit number FERM P-14623.

iii. Construction of K54A Expression Vector and Preparation of Transformed *E.coli*.

An expression plasmid for cDNA coding for K54A mutant was constructed by 2 steps of PCR. In the first PCR, a combination of mutagenized primer 54K F (Seq.Id.No.10) and non-mutagenized primer TCF 977 R (Seq.Id.No.6) and a combination of mutagenized primer 54K R (Seq.Id.No.11) and non-mutagenized primer TCFSal-77 (Seq.Id.No.4) were used. Four ng of pcD TCF001 was used as a template in both reactions. After the reactions, both reaction mixtures were admixed and purified with microcon 100.

One twentieth of the mixture was used as template in the second PCR. TCFSal-77 and TCF 977 R were used as primers. The reaction product was purified with microcone 100 and digested by restriction enzymes BstPI and EcoRV. By using a ligation kit, the fragment was inserted into the large fragment of the SR α -containing TCF expression vector cleaved by BstPI and EcoRV beforehand. *E.coli* DH5 α was transformed with the ligation reaction mixture and an objec-

tive clone was obtained from the obtained ampicillin resistant cells by the same method as described before. Plasmid DNA was prepared from the obtained clone and the DNA sequence thereof was determined by DNA sequencer.

iv. Construction of RGKD132AGAA Expression Vector and Preparation of Transformed E.coli.

An expression plasmide for cDNA coding for RGKD132AGAA mutant was constructed by 2 steps of PCR. In the first PCR, a combination of mutagenized primer 132RGKD F (Seq.ID.No.12) and non-mutagenized primer TCF977R (Seq.ID.No.6) and a combination of mutagenized primer 132RGKD R (Seq.ID.No.13) and primer TCF Sal-77 (Seq.ID.No.4) were used. Four ng of pcD TCF001 was used as a template in both reactions. After the reaction was through, both reaction mixtures were admixed and purified with microcon 100.

One twentieth of the mixture was used as template in the second PCR. TCFSal-77 and TCF977 R were used as primers. The reaction product was purified with microcon 100 and digested by restriction enzymes BstPI and EcoRV. By using a ligation kit, the fragment was inserted into the large fragment of the SR α -containing TCF expression vector cleaved by BstPI and EcoRV beforehand. E.coli DH5 α was transformed with the ligation reaction mixture and an objective clone was obtained from the obtained ampicillin resistant cell lines. Plasmid DNA was prepared from the obtained clone in the same way as described before and the base sequence thereof was determined by DNA sequencer.

v. Construction of R142A Expression Vector and Preparation of Transformed E.coli

An expression plasmid for cDNA coding for R142A mutant was constructed by 2 steps of PCR. In the first PCR, a combination of mutagenized primer 142R F (Seq.ID.No.14) and non-mutagenized primer TCF977 R (Seq.ID.No.6) and a combination of mutagenized primer 142R R (Seq.ID.No.15) and TCFSal-77 (Seq.ID.No.4) were used. Four ng of pcD TCF was used as template in both reactions. After the reaction was through, both reaction mixtures were admixed and purified with microcon 100.

Then, one twentieth of the mixture was used as template in the second PCR. The reaction mixture was purified with microcon 100 and digested by restriction enzymes BstPI and EcoRV. By using a ligation kit, the fragment was inserted into the large fragment of the SR α -containing TCF expression vector cleaved by BstPI and EcoRV beforehand. E.coli DH5 α was transformed with the ligation reaction mixture and an objective clone was obtained from the obtained ampicillin resistant cell lines in the same way as described before. The plasmid DNA was prepared from the obtained clone and the DNA sequence thereof was determined by DNA sequencer.

vi. Construction of R42A Expression Vector and Preparation of Transformed E.coli.

An expression plasmid for cDNA coding for R42A mutant was constructed by 2 steps of PCR. In the first PCR, a combination of mutagenized primer 42R F (Seq.ID.No.16) and non-mutagenized primer TCF977 R (Seq.ID.No.6) and a combination of mutagenized primer 42R R (Seq.ID. No.17) and TCFSal-77 (Seq.ID.No.4) were used. Four ng of pcD TCF001 was used as template in the both reactions.

After the reaction was through, the both reaction mixtures were admixed and purified with microcon 100. One twentieth of the mixture was used as template in the second PCR. TCFSal-77 and TCF977 R were used as primers. The reaction mixture was purified with microcon 100 and was digested by restriction enzyme BstPI/EcoRV. By using a ligation kit, the fragment was inserted into the large fragment of the SR α -containing TCF expression vector cleaved by BstPI and EcoRV beforehand. E.coli DH5 α was transformed with the ligation reaction mixture and an objective clone was obtained from ampicillin resistant cell lines in the same way as described before. The plasmid DNA was prepared from the obtained clone and the DNA sequence thereof was determined by DNA sequencer.

III. Preparation and Purification of Expression Plasmids for TCF Mutants

Six species of transformed E.coli comprising the above expression plasmids were cultured in L broth (400ml) containing 50 μ g/ml ampicillin in a shaking incubator at 37°C overnight, wherein Spectinomycin (Sigma) was added up to a final concentration of 0.3mg/ml when OD600 of cultured broth became 1.0. According to the method of Maniatis (Molecular cloning 2nd ed. pp1.21-1.52 (1989), Cold Spring Harbor Laboratory), plasmid DNA was isolated by alkaline SDS method and 6 species of TCF mutant expression plasmids were purified by cesium density gradient centrifugation method.

IV. Transfection of TCF Mutant Expression Plasmid into Animal Cell.

All the mutant expression plasmids were transfected into Chinese Hamster Ovary (CHO) Cells. CHO cells (2×10^6) were suspended in 0.8ml IMDM medium (Gibco) containing 10% fetal calf serum (FCS) (Gibco), in which a solution of 200 μ g of expression vector and 10 μ g of Blastidicin resistant gene expression plasmid pSV2 bsr (Funakoshi) dissolved

beforehand in 25 μ l of TE (10mM Tris-HCl (pH8.0)-1mM EDTA) was further suspended. This suspension received electroporation under the conditions of 330V and 960 μ F. After leaving it at room temperature for 10 minutes, it was suspended in 10ml of IMDM containing 10% FCS medium and cultured at 37°C in a CO₂ incubator (5% CO₂) for 2 days. Two days after, the supernatant was collected and the amount of the expressed TCF mutant was analyzed by enzyme immunoassay (EIA) (N. Shima, et. al., Gastro-enterologia Japonica, Vol. 26, No. 4. pp477-482 (1991)) using anti-TCF monoclonal antibody. It was used as a sample for assaying biological activity. The cells were harvested from the bottom of flasks by trypsin (Gibco) treatment and the number of viable cells was counted. About 10,000 cells/well were placed in 96-well plates(Nunc) and cultured in 200 μ l/well of IMDM medium containing 10% FCS and 5 μ g/ml Blastcidine for 2-3 weeks. 2-3 weeks after, 50 μ l aliquot was taken from each well and investigated on the expression of TCF mutant by EIA. Cell clones expressing the TCF mutants were grown in 12-well plates and 25 cm² flasks. The cell lines producing TCF mutant were established from CHO cells by the above operation.

V. Large Scale Cultivation of TCF Mutant Producing Cells

Mutant producing cells were harvested from 75 cm² flasks by trypsin treatment when it became confluent and those cells were transferred into 10 225-cm² flasks containing 100ml of the medium and cultured for a week. Then the cultured supernatant was collected. By repeating this operation once or twice, 1 - 2 l of the cultured broth was obtained.

VI. Purification of the TCF mutants

It was purified by 3 steps as described below.

i. Heparin-Sepharose CL-6B

Precipitates were removed from one - two liter of cultured medium of CHO cells expressing each TCF mutants by centrifugation (2,000 rpm x 10 min.) of the medium and filtrating the supernatant through a 0.45 μ m filter (German Science). TCF mutant was adsorbed at 4ml/min. on a heparin-Sepharose CL-6B column (25 mm x 120 mm, Pharmacia) equilibrated with 10mM Tris-HCl (pH 7.5) containing 0.3M NaCl and 0.01% Tween 20. The column was washed with about 500ml of equilibration buffer and the TCF mutant was eluted by 10mM Tris-HCl (pH 7.5) containing 2M NaCl and 0.01% Tween 20. The eluted solution was fractionated to 4ml each by a fraction collector and the fractions having absorption at 280 nm were collected.

ii. Mono S FPLC

The fraction containing TCF mutant eluted with 2M NaCl was dialyzed against 10mM phosphate buffer (pH 7.0) containing 0.15M NaCl, followed by centrifugation (12,000 rpm x 90 min.) to remove precipitate. The supernatant containing TCF mutant was passed through on a Mono S column (5 mm x 50 mm, Pharmacia) equilibrated with 10 mM phosphate buffer (pH 7.0) containing 0.15 M NaCl and 0.01 % Tween 20 at flow rate of 1 ml/min. for TCF mutant to be adsorbed thereon. After the column was washed with about 30 ml of equilibration buffer, TCF mutant was eluted by changing the flow rate to 0.5ml/min, with a linear gradient of NaCl up to 1.0 M for 60 min.. The eluted solution was fractionated to 5ml each by a fraction collector and fractions containing TCF mutant was analyzed by absorption at 280 nm and EIA and collected.

iii. Heparin 5-PW FPLC

To the fraction containing TCF mutant obtained using Mono S column chromatography, 2-fold amount of 10 mM Tris-HCl (pH 7.5) containing 0.01% Tween 20 was added. The solution was passed through a Heparin 5-PW column (5 mm x 75 mm TOSOH) 1 ml/min. equilibrated with 10 mM Tris-HCl (pH 7.5) containing 0.3M NaCl and 0.01% Tween 20 for TCF mutant to be absorbed thereon. By changing the flow rate to 0.5 ml/min., TCF mutant was eluted with a linear gradient of NaCl up to 2.0 M for 60 min.

The eluted solution was fractionated to 5ml each by a fraction collector. The fraction containing TCF mutant was analyzed by 280 nm absorption and EIA and collected. Obtained TCF mutant solution was dialyzed against PBS containing 0.01% of Tween 20 (TPBS) so as to be the final purified product. The amount of protein in the final purified product was determined by Lowry method. The amino acid sequence of TCF mutant RKRR2AAAA and that of mutant KIKTKK27 were represented in Seq.ID.No.18 and in Seq.ID.No.19 respectively.

VII. SDS-polyacrylamide Gel Electrophoresis of Purified TCF Mutant

Purified TCF mutant (200 ng) was applied on SDS polyacrylamide gel electrophoresis. Schematic representation

of electrophoresis of TCF mutant RKRR2AAAA and KIKTKKK27AIATAA, which exhibited 10-fold increase in biological activity as described below, and native TCF was shown in figure 1. Both of the results under reducing conditions (in the presence of β -mercaptoethanol) and non-reducing conditions (in the absence of β -mercaptoethanol) did not show any difference among the three. In addition, there was no band but those to be expected from the structure of both TCF mutants.

[Example 2]

Affinity of TCF and TCF Mutant to Heparin

I. Heparin-Sepharose CL-6B

Precipitates were removed from the cultured medium of CHO cells expressing each TCF mutant by centrifugation (1,200 g x 10 min.) of the medium and by filtrating the supernatant through a 0.22 μ m filter. The filtrated supernatant was charged on a heparin-Sepharose CL-6B column (5mm x 5mm; Pharmacia) equilibrated with TPBS for TCF mutant to be adsorbed thereon. After washing with 3ml TPBS, TCF mutant was eluted with 1 ml of TPBS containing 0.2-0.3M NaCl, increasing the salt concentration stepwise. The concentration of TCF mutant in the eluate was analyzed by EIA and the salt concentration of the eluate was defined as affinity of mutant to heparin.

II. Heparin 5-PW FPLC

The cultured broth of CHO cells expressing each TCF mutant (30-60 ml) was centrifuged (1,000 g x 10 min.), passed through 0.22 μ m filter to remove precipitate and applied on a Heparin 5-PW column equilibrated with 20 mM Tris-HCl buffer solution containing 0.01% Tween 20 at a flow rate of 1.0 ml/min. for TCF mutant to be adsorbed. After washing the column with about 20 ml of equilibration buffer solution and changing the flow rate to 0.5 ml/min., TCF mutant was eluted with a linear gradient of NaCl up to 1.5 M for 45 minutes. Fractions of 0.5 ml each were taken by a fraction collector and the concentration of TCF mutant in each fraction was quantified by EIA and the salt concentration of the elution was defined as affinity of mutant to heparin.

The results of determination of affinity of these TCF mutant to heparin are shown in table 1. The elution concentration of NaCl from heparin-Sepharose represents the concentration at which TCF mutant is eluted in the maximum amount. The relative ratio of elution concentration is defined as (the elution concentration of NaCl of mutant TCF/that of native TCF). And n.d. means "not determined". In the examination with heparin-Sepharose, RKRR2AAAA, KIKTKK27AIATAA, and R42A exhibited significantly lowered affinity to heparin. Further, in the examination with heparin 5-PW, it was observed that affinity of the mutants to heparin was lowered to around 70 % of that of native TCF.

Table 1

	Heparin-Sepharose Elution Concentration of NaCl(M)	Heparin 5-PW Elution Concentration of NaCl(M)	Relative Ratio of Elution concentration
TCF	0.9	1.14	1.00
RKRR2AAAA	0.6	0.78	0.68
KIKTKK27AIATAA	0.6	0.82	0.72
R42A	0.7	0.84	0.74
K54A	0.9	1.10	0.96
RGKD132AGAA	0.9	n.d.	n.d.
R142A	0.9	n.d.	n.d.

[Example 3]

Proliferative Activity of TCF and TCF Mutants on Hepatocyte in vitro

Proliferative activity was investigated by the following method: According to the method of Segren (Method in cell biology, Vol. 13, p29 (1976) Academic Press, New York), hepatocyte was isolated from Wister rats (about 200g of body

weight). The cells ($1.0 \times 10^4/50 \mu\text{l/well}$) were placed into the wells of 96-well plates (Falcon) and cultured at 37°C overnight using Williams E medium (Flow Laboratory) containing 10% fetal calf serum and $10 \mu\text{M}$ dexamethasone (hereinafter, abbreviated as base medium). After 24 hours, $10 \mu\text{l}$ of base medium containing TCF or TCF mutant was added to each well. The plates were incubated at 37°C for another 22 hours. After 22 hours, ^3H -thymidine (Amersham) was added thereto so as to be $1 \mu\text{Ci/well}$, keeping the culture another 2 hours. After then, the cells were washed twice with PBS and harvested by treatment of 0.5% trypsin followed by collection of the cells in a glass filter by cell harvester. The radio activity incorporated in each well was measured by Matrix 96 (Packard) as the amount of DNA synthesis. The results are shown in figure 2. Mutant K54A, RGKD132AGAA and R142A had 1.4-fold, 2.0-fold and 1.6-fold, respectively, higher biological activity than native TCF at a TCF antigen concentration of 2.5 ng/ml . Further each mutant which had lowered affinity to heparin was determined by Lowery method. Then the biological activity was compared with regard to the protein concentration exhibiting 50% of maximum proliferative activity (ED_{50}) (Figure 3 and 4). As the results, 2 species of protein, that is, RKRR2AAAA and KIKTKK27AIATAA, exhibited more than 10 folds of biological activity per unit amount of protein comparing with that of native TCF.

[Example 4]

Proliferative Activity of TCF and TCF Mutant in Kidney Epithelial Cells

Proliferative activity in kidney epithelial cell was determined by the following method:

OK cells derived from kidney epithelial cell line of American Opossum were placed into each well of 96-well plates so as to be $1.0 \times 10^4/100 \mu\text{l/well}$ and cultured in DMEM medium containing 10 % fetal calf serum at 37°C overnight. After then, each well was washed 2-3 times with DMEM medium containing no serum. The medium in each well was replaced with DMEM medium containing no serum and the culture was kept at 37°C for another 2 days. Then, the medium in each well was again replaced with $50 \mu\text{l}$ of fresh DMEM medium containing no serum and, with $50 \mu\text{l}$ of addition of TCF or TCF mutant diluted with DMED medium containing 0.2% bovine serum albumin, the culture was kept for another 24 hours. After 24 hours, ^3H -thymidine was added thereto so as to be $1 \mu\text{Ci/well}$ and the culture was kept for another 2 hours. Then, cells were washed with PBS twice and the cells were harvested by treatment of 0.5% trypsin, followed by collection of the cells in a glassfilter by a cell harvester. The radio activity incorporated in each well was measured by Matrix 96 and determined as the amount of DNA synthesis. The results were exhibited in figure 5. As the results, it was observed that biological activities per unit amount of protein of RKRR2AAAA and KIKTKK27AIATAA in kidney epithelial cell increased more than 2 folds comparing with that of native TCF.

[Example 5]

Proliferative Activity of TCF and TCF Mutant in Bone Marrow Cell in vitro

Proliferative activity in bone marrow cell was determined by the following method:

NFS-60 cells which are from a mouse bone marrow cell line were placed into each well of 96 well-plate so as to be $5.0 \times 10^4 \text{ cells}/50 \mu\text{l/well}$ in RPMI medium containing 10% fetal calf serum and, with addition of $50 \mu\text{l}$ of TCF or TCF mutant diluted with the medium, cultured at 37°C for 24 hours. After 24 hours, $10 \mu\text{l}$ of 5 mg/ml MTT (Sigma) was added to each well and the culture was kept for another 4 hours. Then, $100 \mu\text{l}$ of 10% SDS/10mM ammonium chloride was added to each well and it was left at room temperature overnight. After that, optical absorbance at 590 nm was measured by Immunoreader NJ-2000 (Intermed) as proliferative activity.

The results were exhibited in figure 6. As the results, it was observed that biological activities per unit amount of protein of RKRR2AAAA and KIKTKK27AIATAA in bone marrow cell decrease to 1/2-1/20 of that of native TCF.

[Example 6]

In vivo Biological Activity of TCF and TCF Mutants

In vivo Biological activity was assayed by the following method:

TCF or TCF mutant dissolved in PBS containing 0.01% Tween 20 was intravenously administered through tail ($2 \text{ ml/kg} \times 2 \text{ times/day}$) in 6 weeks old male Wister rats for 4 days.

At the next day to the final administration, blood samples were taken from caudal vena cava under ether anesthesia and serum thereof were collected by centrifugation ($3000 \text{ rpm} \times 10 \text{ min.}$) and, in the case of plasma, immediately after sampling blood, sodium citrate (the final concentration was 0.38%) was added thereto followed by centrifugation ($3000 \text{ rpm} \times 10 \text{ min.}$) to give plasma. After serum or plasma obtained was preserved in a freezer kept at -30°C , serum level of total protein, albumin, unsaturated iron binding capacity, total cholesterol, free cholesterol, HDL-cholesterol and phospholipid were analyzed by serum autoanalyzer (Hitachi 7150 Autoanalyzer) and plasma level of prothrombin time and fibrin-

ogen were analyzed by Auto blood coagulation analyzer KC40 (Amerung). For these analysis, the following analyzing kits were used:

Total protein: Autosera^{TR} TP, Albumin: Autosera^{TR} ALB,
 5 Unsaturated iron-binding capacity: Clinimate^{TR} UIBC,
 Total cholesterol: Autosera^{TR} CHO-2, Free cholesterol: Autosera^{TR}
 F-CHO-2, HDL-cholesterol: HDL-C · 2 "DAIICHI", Phospholipid: Autosera^{TR} PL-2,
 (All the above kits were products of Daiichi-Pure Chemicals Co., Ltd.)

10 Prothrombin time: Orthobrain thromboplastin (Ortho Diagnostic System Inc.), Fibrinogen: Sun assay Fib (Nitto Boseki Co., Ltd.). As typical examples, dose effects thereof on serum level of total protein and on serum level of HDL-cholesterol were exemplified in figure 7 and figure 8 respectively.

According to the results of statistical analysis of parallel line assey, with respect to increase of total protein, RKRR2AAAA exhibited 2.12 folds of specific activity and KIKIKTKK27AIATAA exhibited 1.37 folds of specific activity,
 15 comparing to that of native one. Further, with respect to increase HDL-cholesterol, RKRR2AAAA exhibited 1.66 folds of specific activity and KIKTKK27AIATAA exhibited 1.62 folds of specific activity, comparing to that of native one.

Industrial Availabilities

20 The present invention is to provide a novel TCF mutant. The TCF mutant of the present invention has proliferative activity and growth stimulative activity in hepatocyte and beneficial for treatment of various hepatic diseases and as an antitumor agent.

SEQUENCING LIST

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STRANDEDNESS: 1
TOPOLOGY: linear
MOLECULAR TYPE: other nucleic acid, synthetic DNA
FEATURE: primer Pst01
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TYPE: nucleic acid
STRANDEDNESS: 1
TOPOLOGY: linear
MOLECULAR TYPE: other nucleic acid, synthetic DNA
FEATURE: primer TCF415 R
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TYPE: nucleic acid
STRANDEDNESS: 1
TOPOLOGY: linear
MOLECULAR TYPE: other nucleic acid, synthetic DNA
FEATURE: primer P002
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SEQ.ID.NO.: 4

LENGTH: 32

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STRANDEDNESS: 1

TOPOLOGY: linear

10 MOLECULAR TYPE: other nucleic acid, synthetic DNA

FEATURE: primer TCFSal-77

SEQUENCE: GGTCG ACTAG GCACT GACTC CGAAC AGGAT TC

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TYPE: nucleic acid

STRANDEDNESS: 1

TOPOLOGY: linear

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FEATURE: primer 2RKRR F

SEQUENCE: CCCTA TGCAG AGGGA CAAGC GGCAG CTGCC ATT

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LENGTH: 23

TYPE: nucleic acid

STRANDEDNESS: 1

40 TOPOLOGY: linear

MOLECULAR TYPE: other nucleic acid, synthetic DNA

FEATURE: primer TCF977 R

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LENGTH: 33

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STRANDEDNESS: 1

TOPOLOGY: linear

10 MOLECULAR TYPE: other nucleic acid, synthetic DNA

FEATURE: primer 2RKRR R

SEQUENCE: GAATT CATGA ATTGT ATTGG CAGCT GCCGC TTG

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SEQ.ID.NO.: 8

20 LENGTH: 35

TYPE: nucleic acid

STRANDEDNESS: 1

25 TOPOLOGY: linear

MOLECULAR TYPE: other nucleic acid, synthetic DNA

FEATURE: primer 27KIKTKK F

SEQUENCE: GGCAA TAGCA ACCGC AGCTG TGAAT ACTGC AGACC

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LENGTH: 38

TYPE: nucleic acid

STRANDEDNESS: 1

40 TOPOLOGY: linear

MOLECULAR TYPE: other nucleic acid, synthetic DNA

FEATURE: primer 27KIKTKK R

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STRANDEDNESS: 1

TOPOLOGY: linear

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TOPOLOGY: linear

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MOLECULAR TYPE: other nucleic acid, synthetic DNA

FEATURE: primer 132RGKD F

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STRANDEDNESS: 1

TOPOLOGY: linear

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STRANDEDNESS: 1

TOPOLOGY: linear

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STRANDEDNESS: 1

40 TOPOLOGY: linear

MOLECULAR TYPE: other nucleic acid, synthetic DNA

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STRANDEDNESS: 1

TOPOLOGY: linear

10 MOLECULAR TYPE: other nucleic acid, synthetic DNA

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20 LENGTH: 27

TYPE: nucleic acid

STRANDEDNESS: 1

TOPOLOGY: linear

25 MOLECULAR TYPE: other nucleic acid, synthetic DNA

FEATURE: primer 42R R

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TYPE: amino acid

STRANDEDNESS: 1

MOLECULAR TYPE: protein

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-25

-20

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-15

-10

-5

-1 1

Ala Ala Ala Ala Asn Thr Ile His Glu Phe Lys Lys Ser Ala Lys Thr

5

10

15

Thr Leu Ile Lys Ile Asp Pro Ala Leu Lys Ile Lys Thr Lys Lys Val

20

25

30

Asn Thr Ala Asp Gln Cys Ala Asn Arg Cys Thr Arg Asn Lys Gly Leu

35

40

45

Pro Phe Thr Cys Lys Ala Phe Val Phe Asp Lys Ala Arg Lys Gln Cys

50

55

60

65

Leu Trp Phe Pro Phe Asn Ser Met Ser Ser Gly Val Lys Lys Glu Phe

70

75

80

Gly His Glu Phe Asp Leu Tyr Glu Asn Lys Asp Tyr Ile Arg Asn Cys

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280

285

10

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290

295

300

305

15

Glu Asn Phe Lys Cys Lys Asp Leu Arg Glu Asn Tyr Cys Arg Asn Pro

310

315

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Asp Gly Ser Glu Ser Pro Trp Cys Phe Thr Thr Asp Pro Asn Ile Arg

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340

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Asp Cys Tyr Arg Gly Asn Gly Lys Asn Tyr Met Gly Asn Leu Ser Gln

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MOLECULAR TYPE: protein

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-20

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-15

-10

-5

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40

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Pro Phe Thr Cys Lys Ala Phe Val Phe Asp Lys Ala Arg Lys Gln Cys

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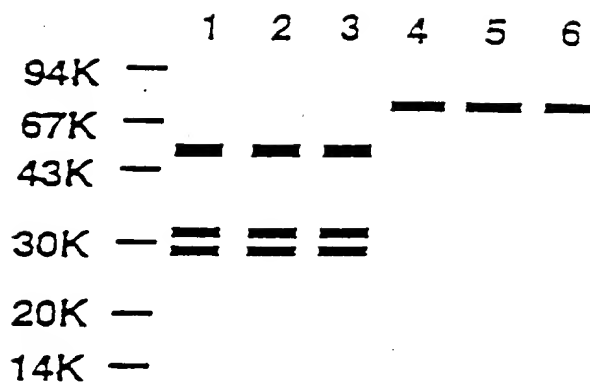
Claims

1. A TCF mutant which is obtained by mutagenesis of more than one amino acid residue at the position from N-termi-

nus to the first kringle of the amino acid sequence of native TCF and has lowered affinity to heparin and/or elevated biological activity.

2. The TCF mutant according to claim 1, wherein Arg2-Lys-Arg-Arg5 of native TCF is mutagenized to Ala-Ala-Ala-Ala.
3. The TCF mutant according to claim 1, wherein Lys27-Ile-Lys-Thr-Lys-Lys32 of native TCF is mutagenized to Ala-Ile-Ala-Thr-Ala-Ala.
4. The TCF mutant according to claim 2 or 3, wherein proliferative activity thereof per unit amount of protein in hepatocyte is more than 10 folds than that of native TCF.
5. The TCF mutant according to claim 2 or 3, wherein proliferative activity thereof per unit amount of protein in kidney epithelial cell is more than 2 folds than that of native TCF.
6. The TCF mutant according to claim 2 or 3, wherein proliferative activity thereof per unit amount of protein in bone marrow cell is 1/2-1/20 of that of native TCF.
7. The TCF mutant according to claim 1, wherein Lys54 of native TCF is mutagenized to Ala.
8. The TCF mutant according to claim 1, wherein Arg132-Gly-Lys-Asp135 of native TCF is mutagenized to Ala-Gly-Ala-Ala.
9. The TCF mutant according to claim 1, wherein Arg142 of native TCF is mutagenized to Ala.
10. The TCF mutant according to claim 1, wherein Arg42 of native TCF is mutagenized to Ala.

Fig. 1



1.Reduced TCF

2.Reduced RKRR2AAAA

3.Reduced KIKTKK27AIATAA

4.Non-reduced TCF

5.Non-reduced RKRR2AAAA

6.Non-reduced KIKTKK27AIATAA

Fig. 2

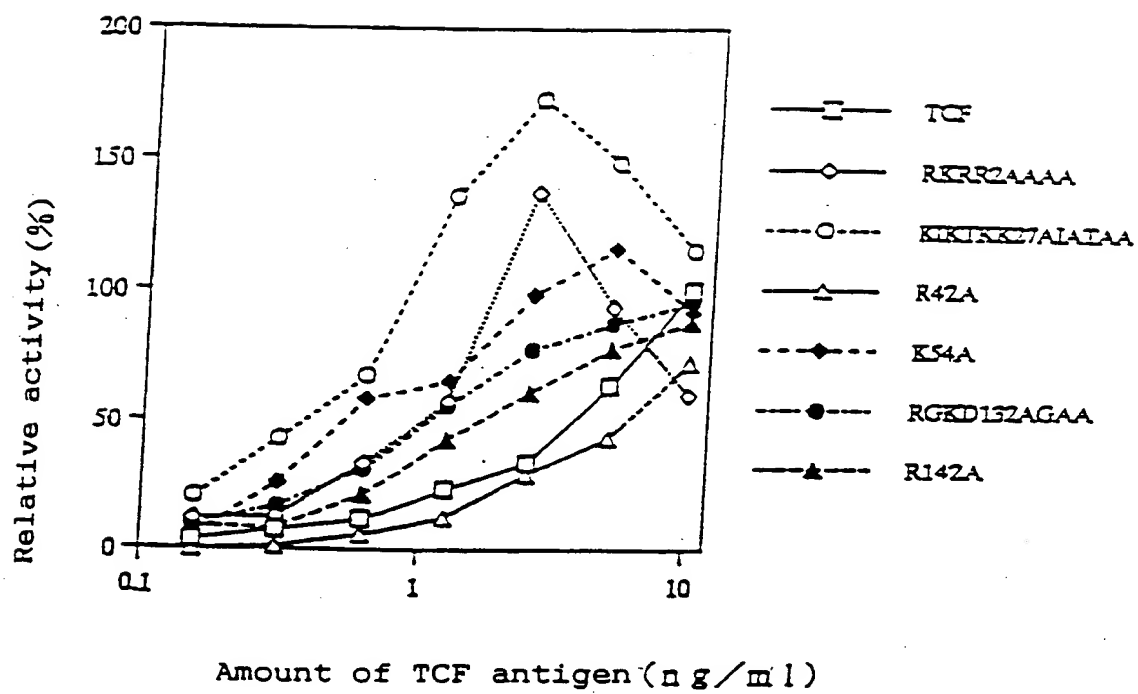


Fig. 3

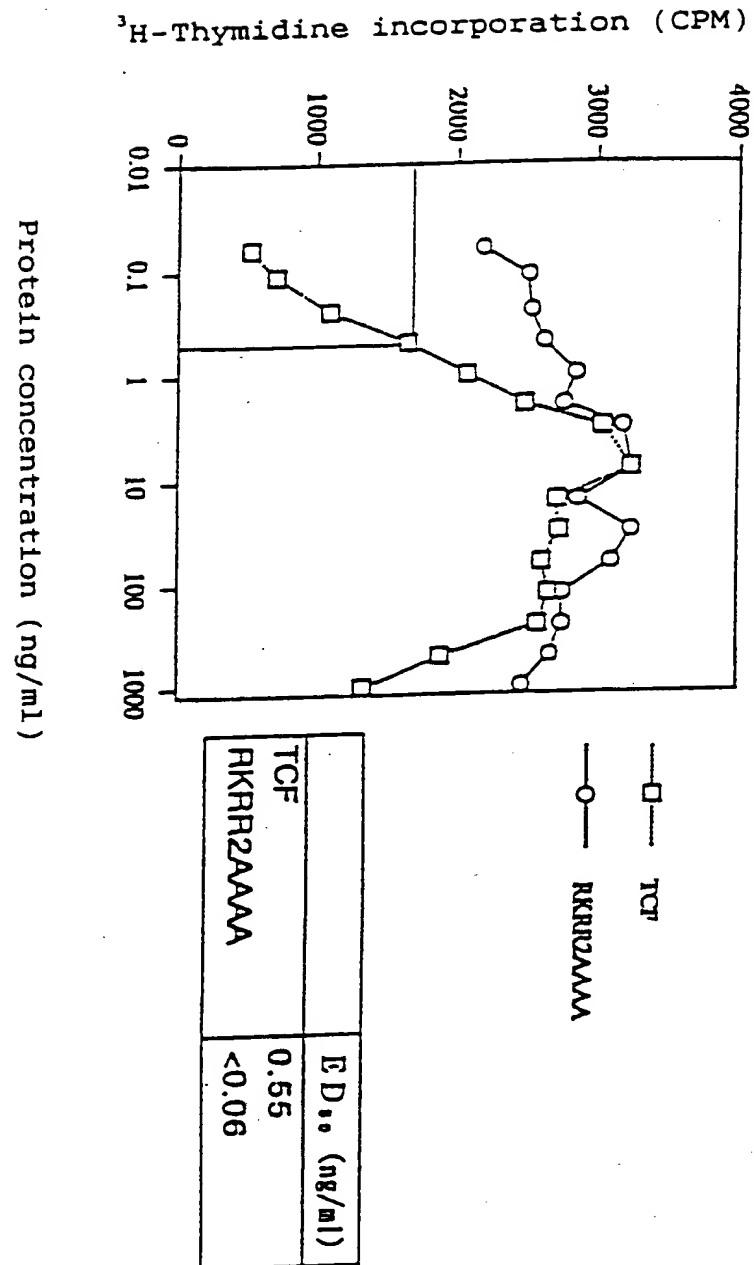


Fig. 4

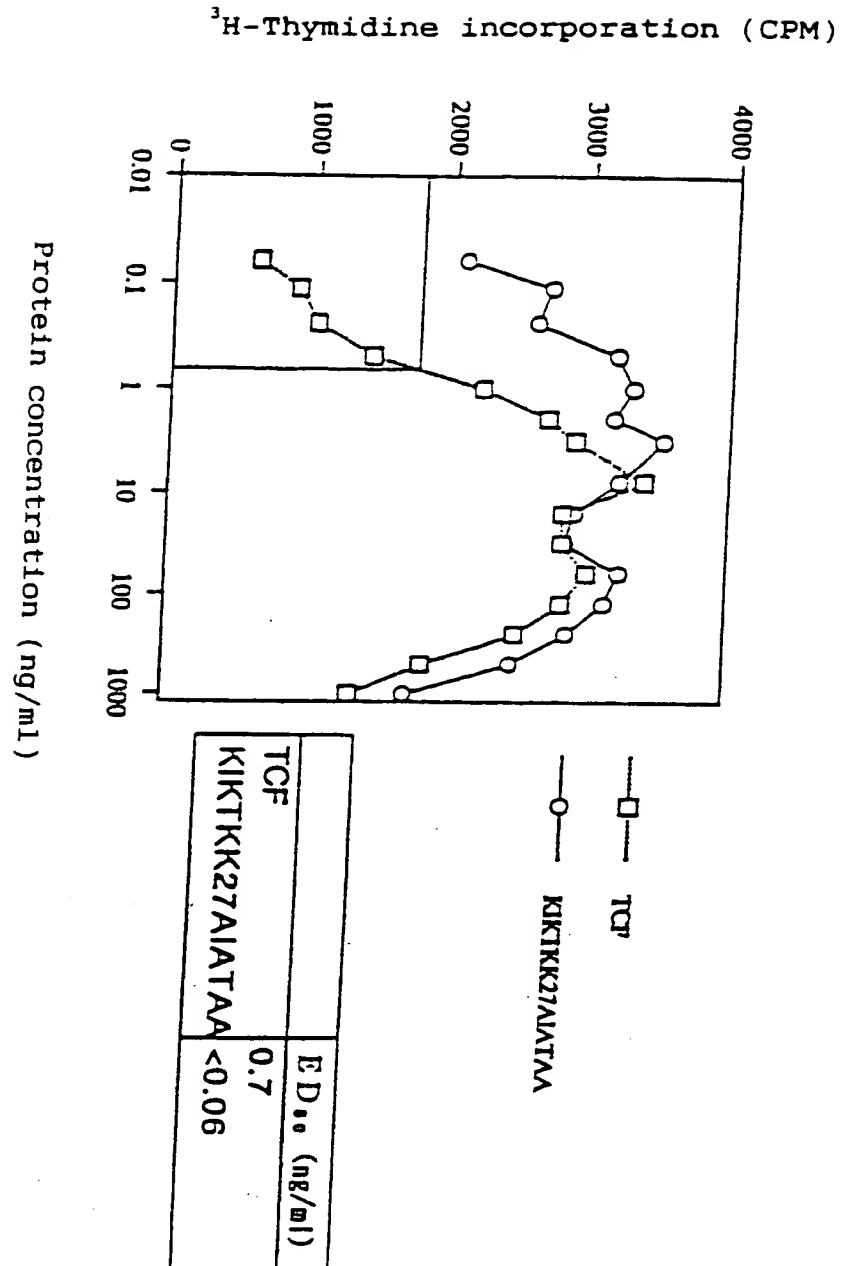


Fig. 5

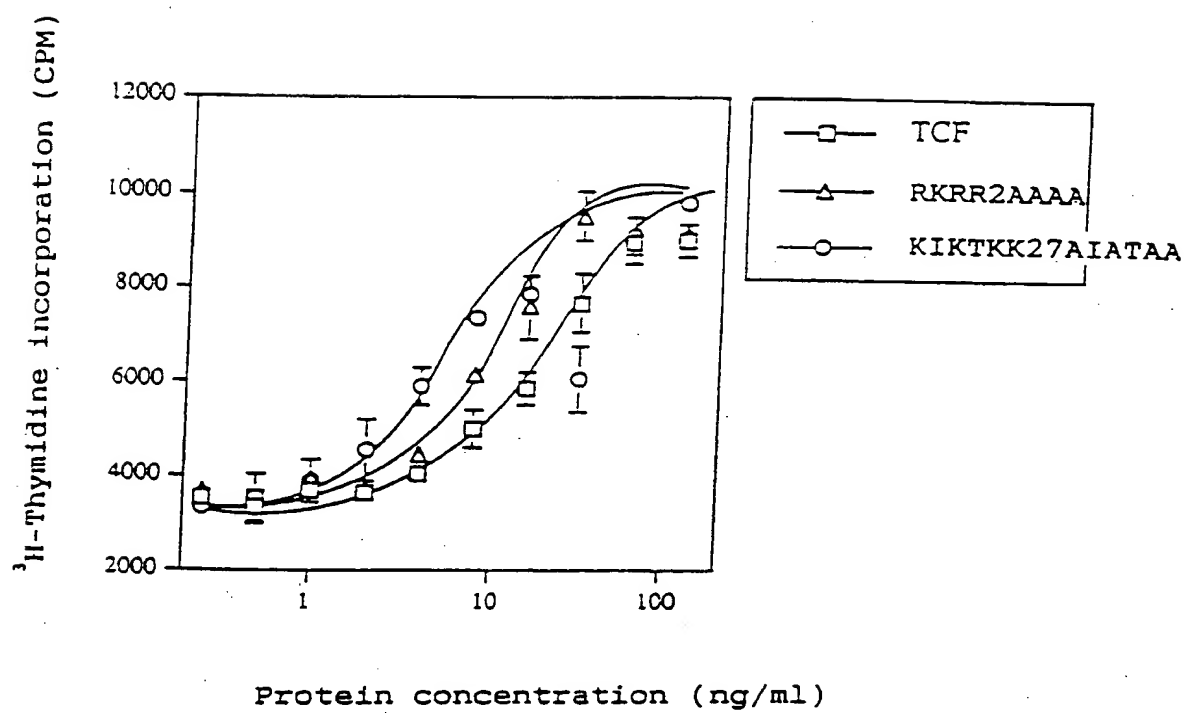


Fig. 6

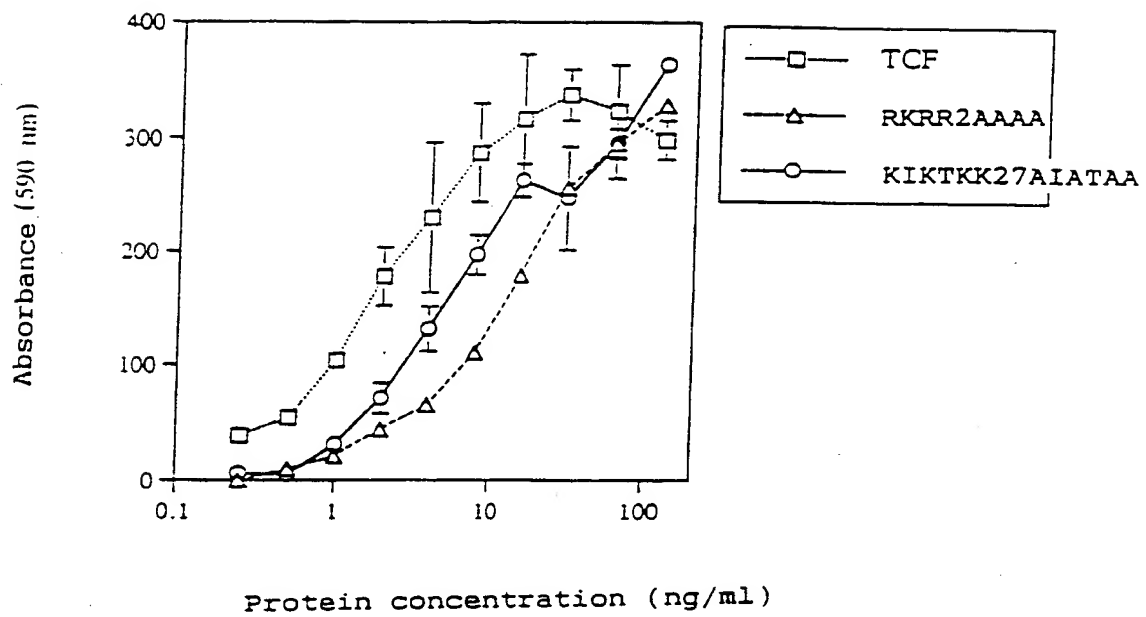


Fig. 7

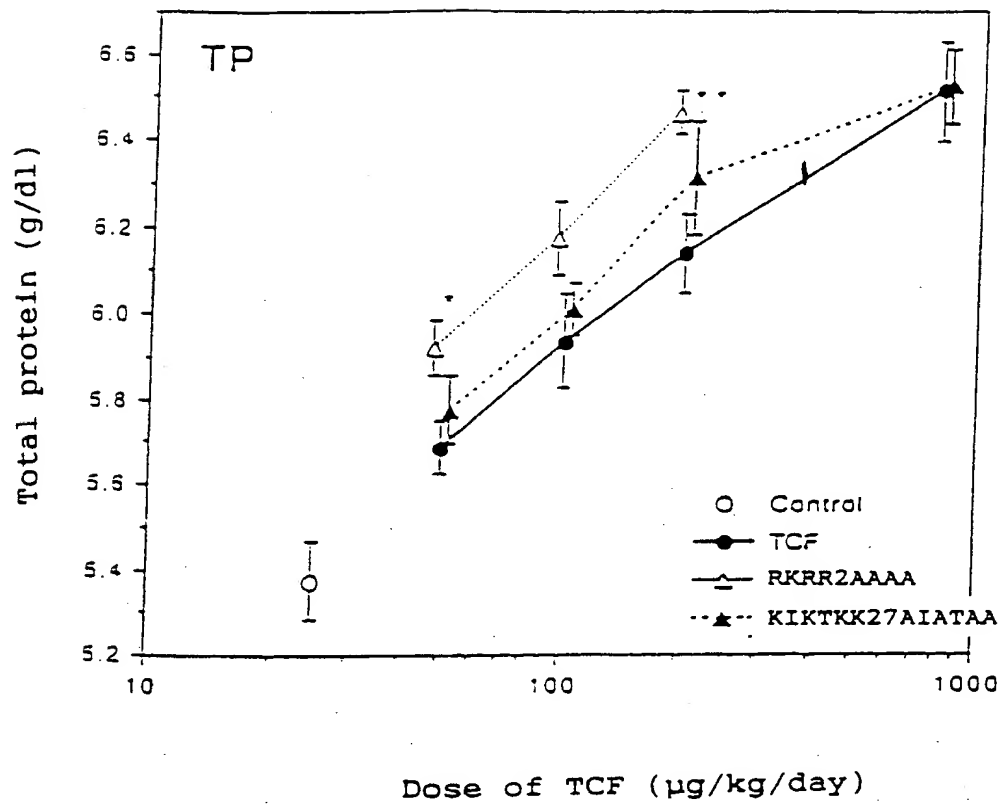
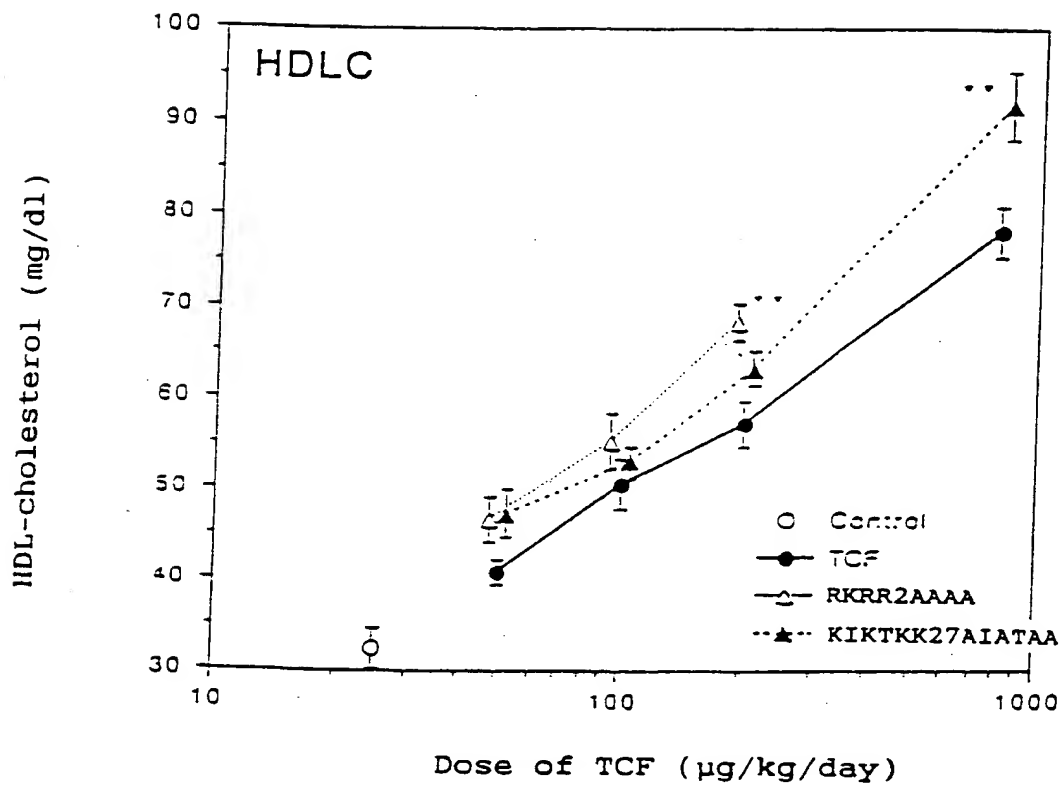


Fig. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP95/02708

A. CLASSIFICATION OF SUBJECT MATTER Int. C1 ⁶ C07K14/52, C12N15/19, C12P21/02 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) Int. C1 ⁶ C07K14/52, C12N15/00, C12P21/02 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CAS ONLINE, BIOSIS PREVIEWS, WPI, WPI/L		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y/A	WO, 90/10651, A1 (Snow Brand Milk Products Co., Ltd.), September 20, 1990 (20. 09. 90) & JP, 2-504271, A1 & EP, 462277, A1	1/2-10
Y/A	Nucleic Acids Res., Vol. 10, No. 20, 1982, M. J. Zoller et al. "Oligonucleotide-directed mutagenesis using M13-derived vectors" p. 6487-6500	1/2-10
Y/A	Biochemistry, Vol. 31, No. 4, 1992, J. LAWLER et al. "Expression and mutagenesis of thrombospondin" p. 1173-1180	1/2-10
Y/A	Eur. J. Haematol, Vol. 47, No. 5, 1991, M. Donner et al. "An arginine-545-cysteine-545 substitution mutation of the von Willebrand factor in type IIb von Willebrand's disease" p. 342-345	1/2-10
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search March 19, 1996 (19. 03. 96)		Date of mailing of the international search report April 9, 1996 (09. 04. 96)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.		Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

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